Wind Power Impacts on System Operation: *A Case Study*

EPA Wind Energy Modeling Workshop

Washington, DC

June 13, 2003

J. Charles Smith

Utility Wind Interest Group

Project History

- Broad based UWIG project prioritization effort
- Operating impacts determined to be most significant issue affecting large-scale integration of wind generation into electric utility systems
- Satisfactory resolution will enable deployment of significant amounts of wind energy in the near term.
- Xcel Energy (NSP) offered to serve as host utility and provide data for the study.
- BPA expanded the study as additional host utility.

Utility
Wind
Interest
Group

Project Overview

- Intermittent nature of wind generation introduces new variables into the power system control problem
- Previous studies often oriented toward maximum allowable wind generation penetration level with no operating impact expected
- Wind generation development has progressed to the point that individual projects have reached size of medium to large conventional plant
- Work was based on actual case study data

Utility Wind Interest Group

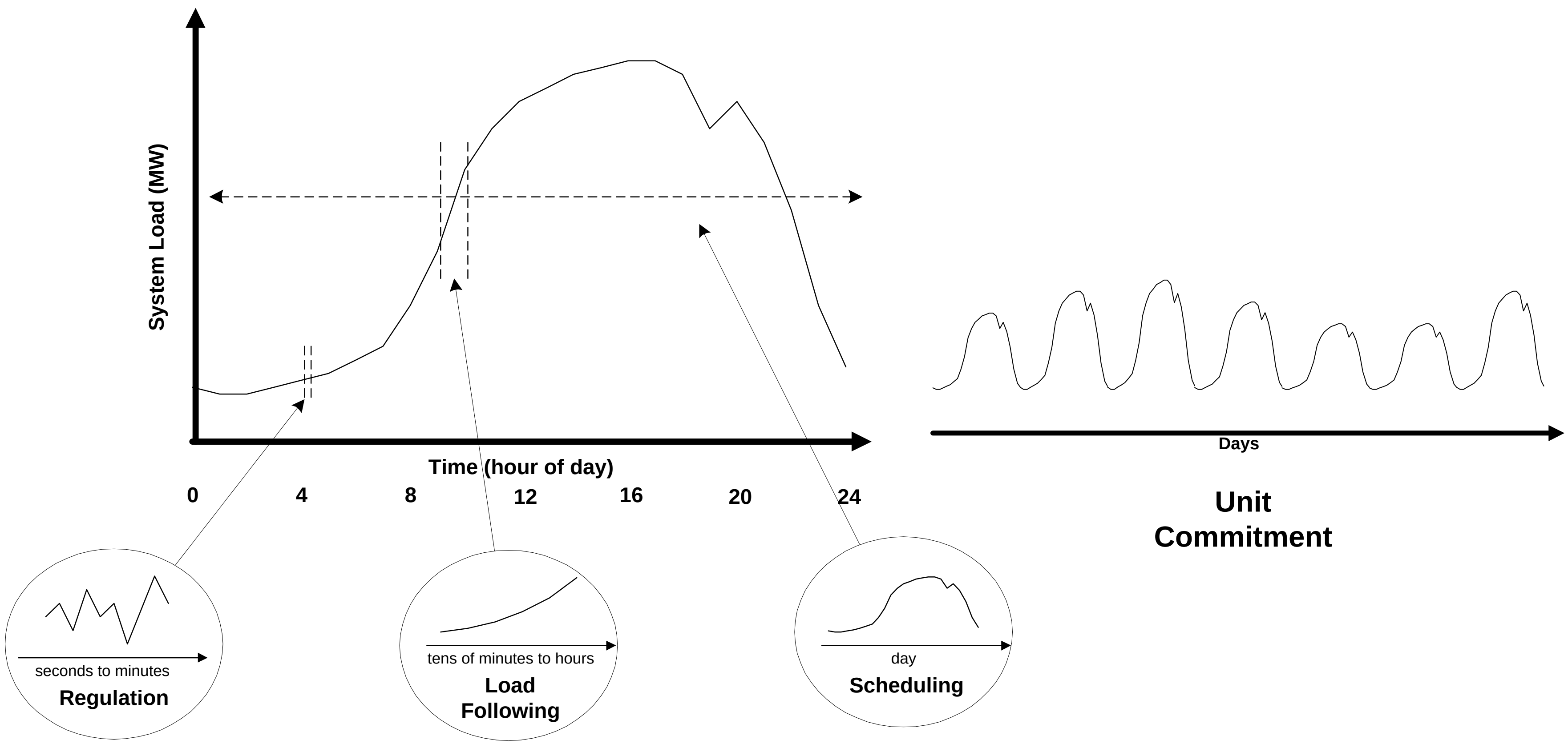
Project Objectives

- Conduct a quantitative investigation of large wind plant operating impacts on utility operations planning
- Identify operating cost impacts for the target system
- Identify opportunities to minimize impacts through changes in wind turbine design and operating practices
- Evaluate value of reduced wind forecast uncertainty
- Identify opportunities to minimize impacts through changes in utility operations planning practices

What Is It ? & What Is It Not?

- It is the development of a new methodology to study the issue
- It is a case study
- Results will depend on generation mix, fuel costs, & wind characteristics
- It is a snapshot in time which varies from periods of a few seconds to a few weeks in duration
- It is not an annual simulation
- It is not easily generalized to different systems

Study Time Frames



Windplants and Operating Issues/Impacts

- Frequency control: *Do windplants make it more difficult to regulate “frequency”?*
- Regulation: *Can windplants affect or increase the area control error (ACE)?*
- Load following: *What happens if windplant output decreases in the morning when load is increasing?*
- Scheduling: *How can committed units be scheduled for the day if windplant output cannot be predicted? What happens if the wind forecast is inaccurate?*
- Committing generating units: *Looking out over the next few to several days, how should or could windplant production be factored into planning what generation units need to be available? Is the effective amount of reserves influenced?*

Case Study Context

- Xcel Energy – North (NSP)
  - Thermal system
  - 250 MW wind generation – existing
  - NREL monitoring of existing windplant

Xcel Approach

- Develop method for creating time-series production profiles for subject windplants
  - Multiple profiles for statistical characterization
- Perform operation simulations
  - Unit Commitment and Scheduling
  - Load following
  - Load-Frequency Control
- Characterize results for each wind production profile as statistical distribution (Monte Carlo)
- Results provide conservative estimate using vertically integrated utility tools/methods based on stated assumptions
  - Additional sensitivities/assumptions identified for further analysis

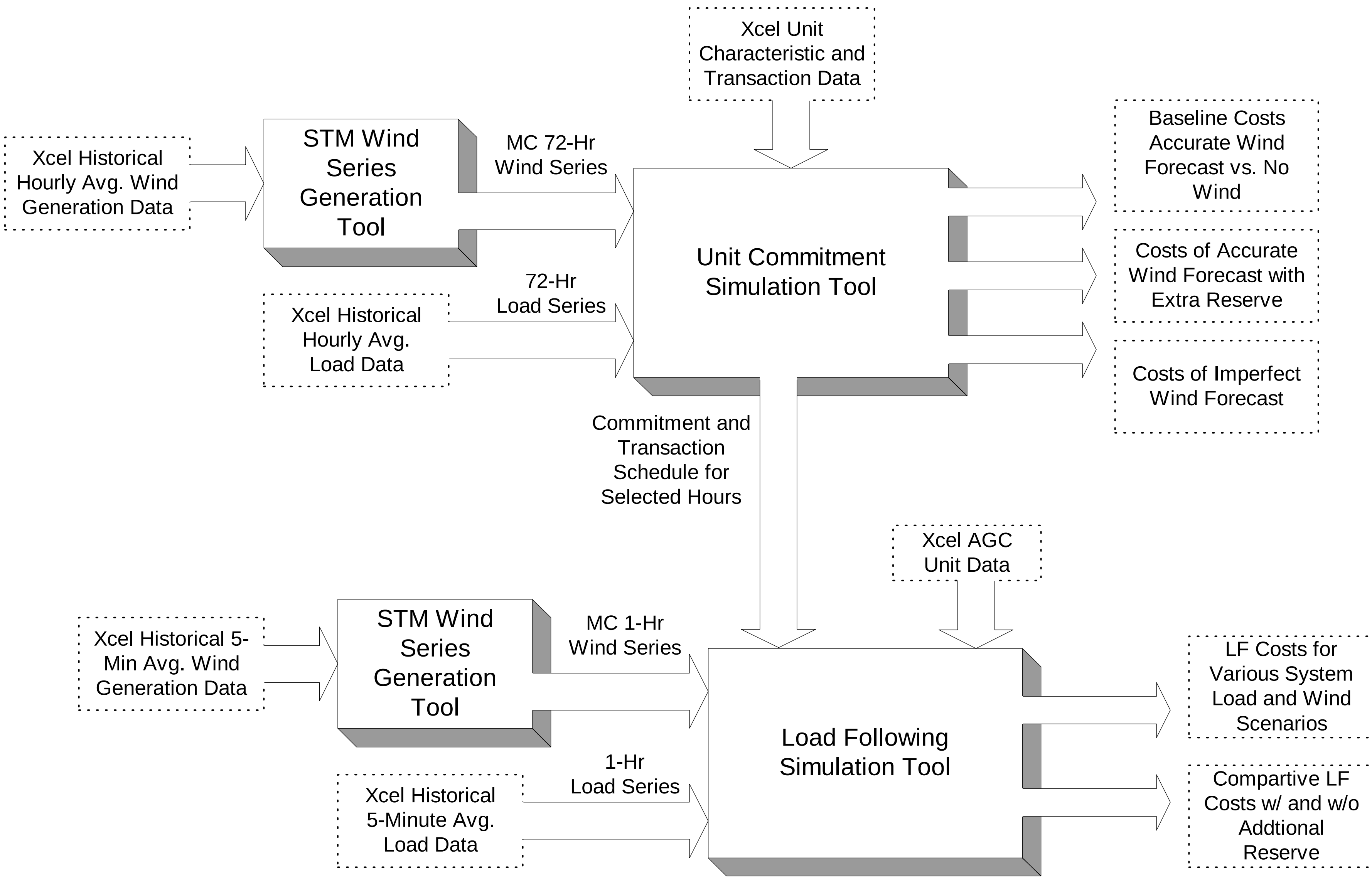
Model Development

- Unit Commitment
  - Hourly resolution for 72-hour horizon
  - Dynamic programming solution
  - ABB CougerPlus program
- Load Following (Econ. Dispatch)
  - 5-min resolution for 1-hour horizon
  - Linear programming solution
- Load Frequency Control
  - 4-sec resolution for 1-hour horizon
  - Classical feedback control solution
  - Modification of commercial AGC algorithm

Wind Modeling

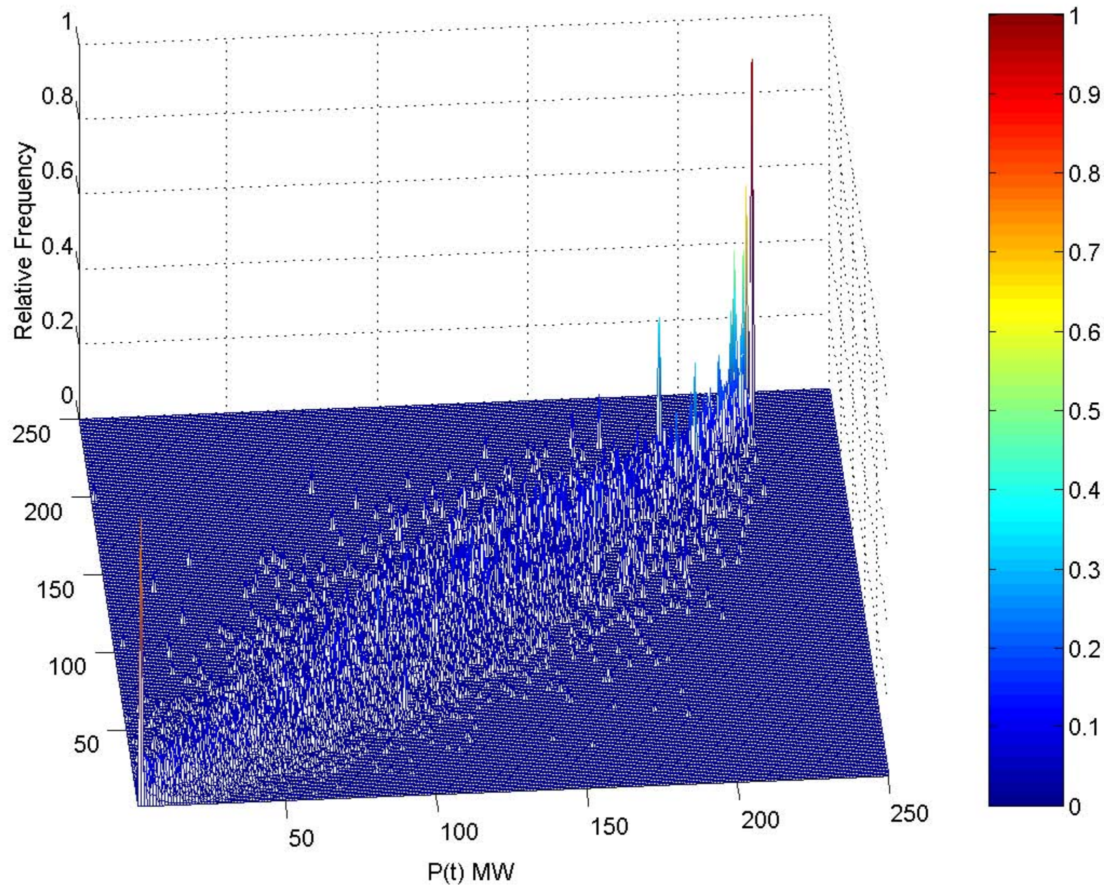
- Approach requires chronological time series data
- Relied extensively on measurement from NSP and NREL databases
- Used State Transition Matrix (STM) and Markov techniques previously applied by NREL

Xcel Analysis Framework

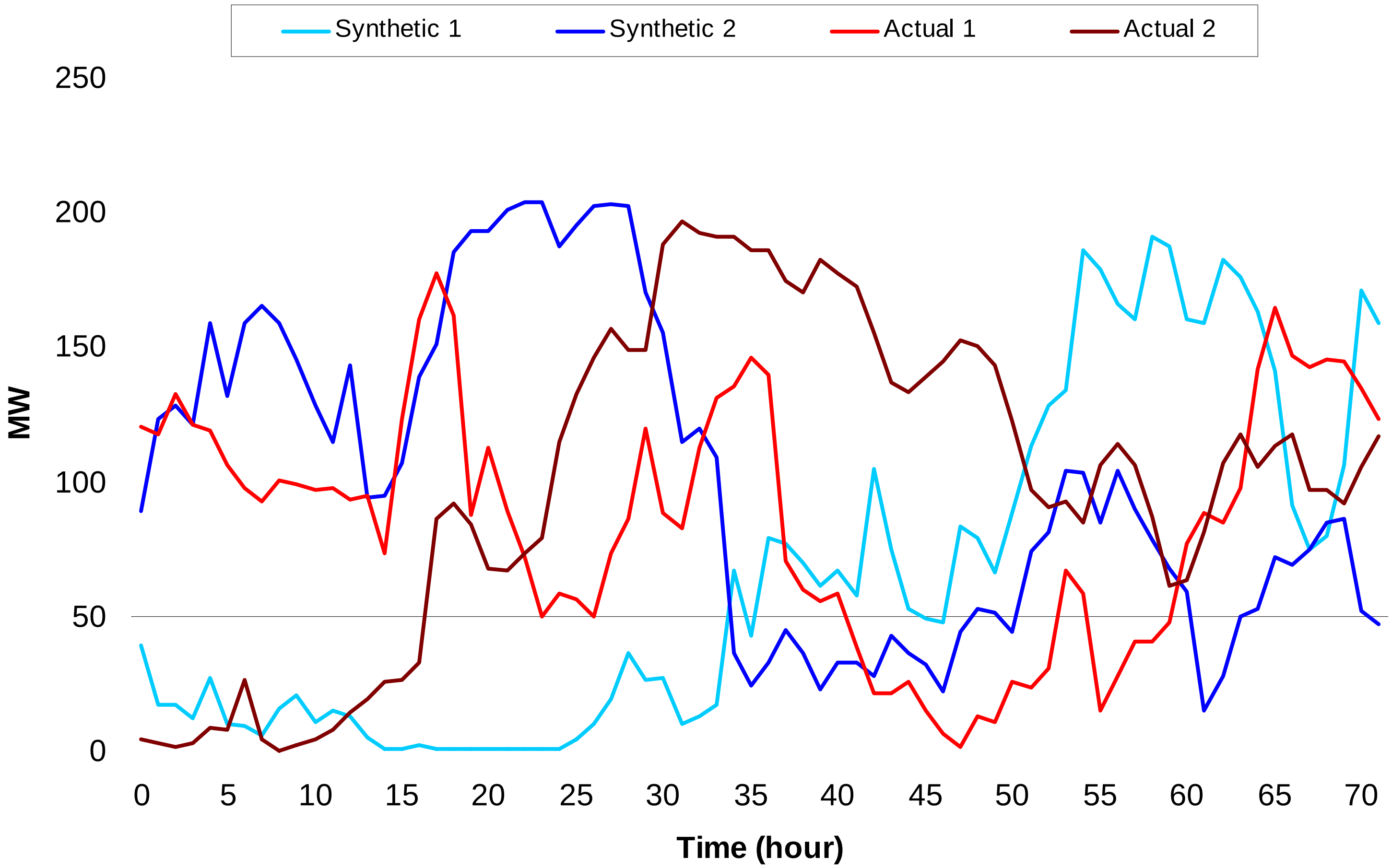


Results – Wind Model

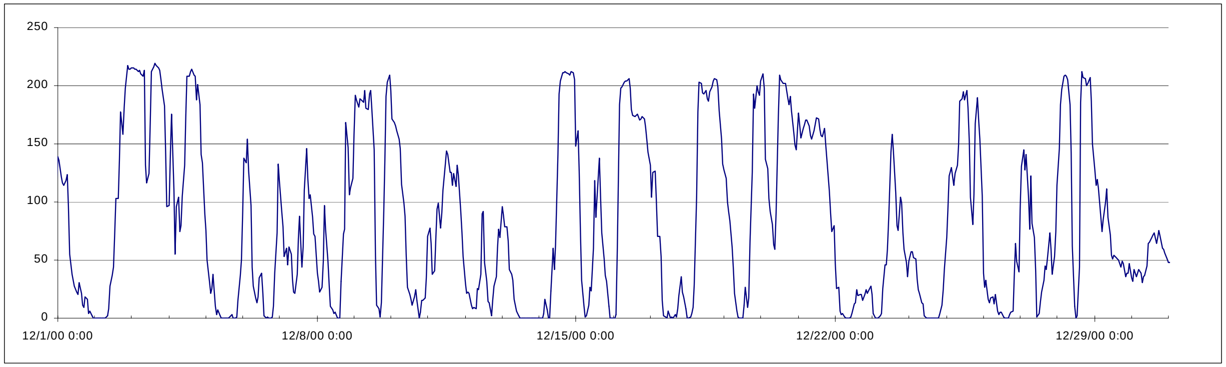
- Developed STMs for hourly, min, and sec levels to synthesize wind gen time series with similar statistical characteristic as the historical data
- Determined regulating reserve requirement through statistical analysis
  - For current 3 to 4%, penetration regulating reserve requirement is increased by about 5%

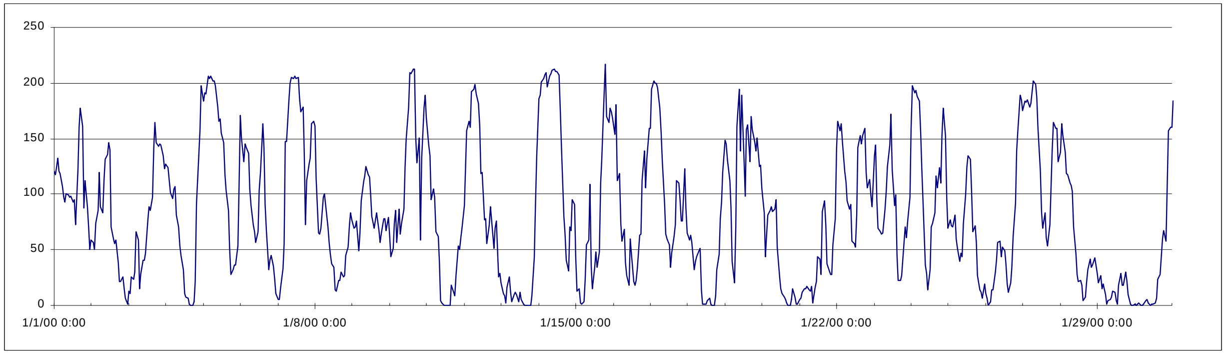


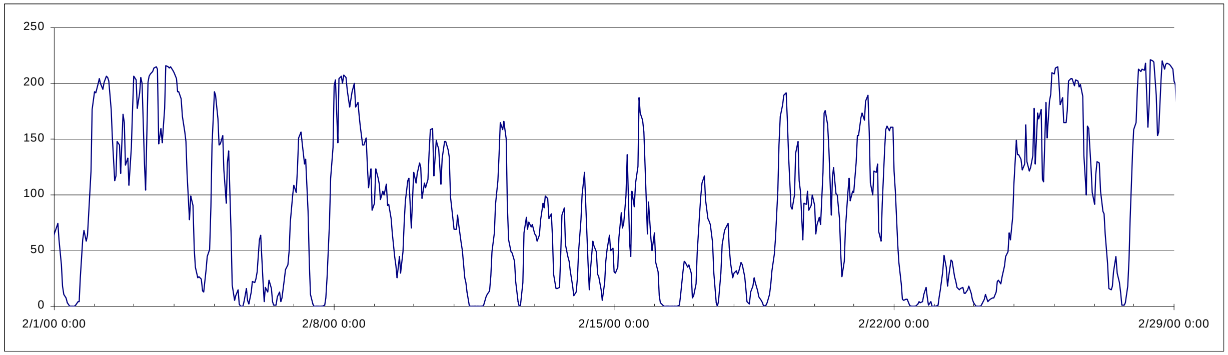
Hourly Wind Model Output vs. Actual



Winter 2000 Actual Hourly Wind Generation







Results – Unit Commitment

- With additional reserve requirement to accommodate wind, determined cost for carrying the additional amounts of reserve.
- Determined additional operating cost due to wind generation forecast inaccuracy. Both over-optimistic and over-pessimistic forecasting result in real-time operation adjustment; hence extra cost.
- Based on cost of forecast inaccuracy, derived a strategy for the amount of wind generation to use in operation planning.
- Results sensitive of fuel price data and utility operating procedure

x %, the range of forecasting error	Cost of forecast inaccuracy $ / MWh
10	0.28
20	0.55
30	0.83
40	1.10
50	1.38

Results – Intra-Hour Load Following

- Intra-hour load following of wind generation variation was simulated by performing economic dispatch over an hour with 5-minute resolution
  - In the event of insufficient amount of reserve from economic units to be deployed for load following, additional generation obtained from dispatching peaker generation or purchasing from spot market
- For base case of existing NSP operating strategy, intra-hour LF cost of wind integration approximately $0.43/MWh
  - This value is sensitive to system operating procedures and modeling assumptions
- Performed additional cases to determine the total cost impact of modifying existing operating strategy to include additional reserves for following wind

Methodology for Evaluating Regulation Impact

- Comparison of area control error (ACE) statistics with and without wind generation in control area
- Evaluation performed using a utility-style Load Frequency Control simulation tool
  - AGC control algorithm currently used by a large utility in WSCC region
  - Closely represents Xcel North strategy for assigning units on AGC control
- Simulations performed for 1-hour horizon with 4-second resolution
  - Sufficient load-following reserves allocated to cover slow variation of load change throughout the hour
  - Ramping limitations of generating units modeled

Simulation Scenarios

- 4 representative hours during the day in summer season
  - For each hour, 4 different system load time series fluctuating around the general trend based on historical data
  - For each hour, 2 different wind generation time series fluctuating around the general trend based on historical data
  - Total of 12 simulations for each of the 4 hours
    - 8 combinations of load and wind time series
    - 4 without wind simulations
- 60 MW regulating reserve for both with and without wind generation scenarios

Results – Wind Model

- Comparison of standard deviations of the ACE for simulations with and without wind for each hour shows little change
- When evaluated on 4-second resolution, small increase in ACE variation for all hours

Hour of Day	Without WG	With WG	% Change
3	14.1622	14.1745	0.08678
8	16.8842	16.8972	0.07694
14	12.8812	12.8885	0.05664
23	14.9126	14.9497	0.24817

- When evaluated on 1-minute resolution, small change in ACE variation for all hours, with a decrease for 3 of the hours

Hour of Day	Without WG	With WG	% Change
3	12.3548	12.3369	-0.1451
8	15.3375	15.3297	-0.0509
14	10.9075	10.9025	-0.0459
23	13.3211	13.3477	0.19929

What does it all mean?

- Simulation model based on vertically integrated utility tools/methods was developed
- Methodologies/assumptions selected provide conservative view of impact of wind integration
- Actual numbers are sensitive to system operating procedures and assumptions made
- < 2$/MWh

Xcel Case Study – Where to from here?

- Complete final report
- Further explore critical sensitivities
  - Generation mix
  - Fuel cost
  - Penetration level
  - Various market scenarios